Preferred citation style

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Design loads for road infrastructures: A new approach

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May 2007

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Context

- PhD dissertation M. Bernard
- Sponsor: ASTRA research funding of VSS projects
- Purpose: Update of current Swiss design load norm

Confusion in application

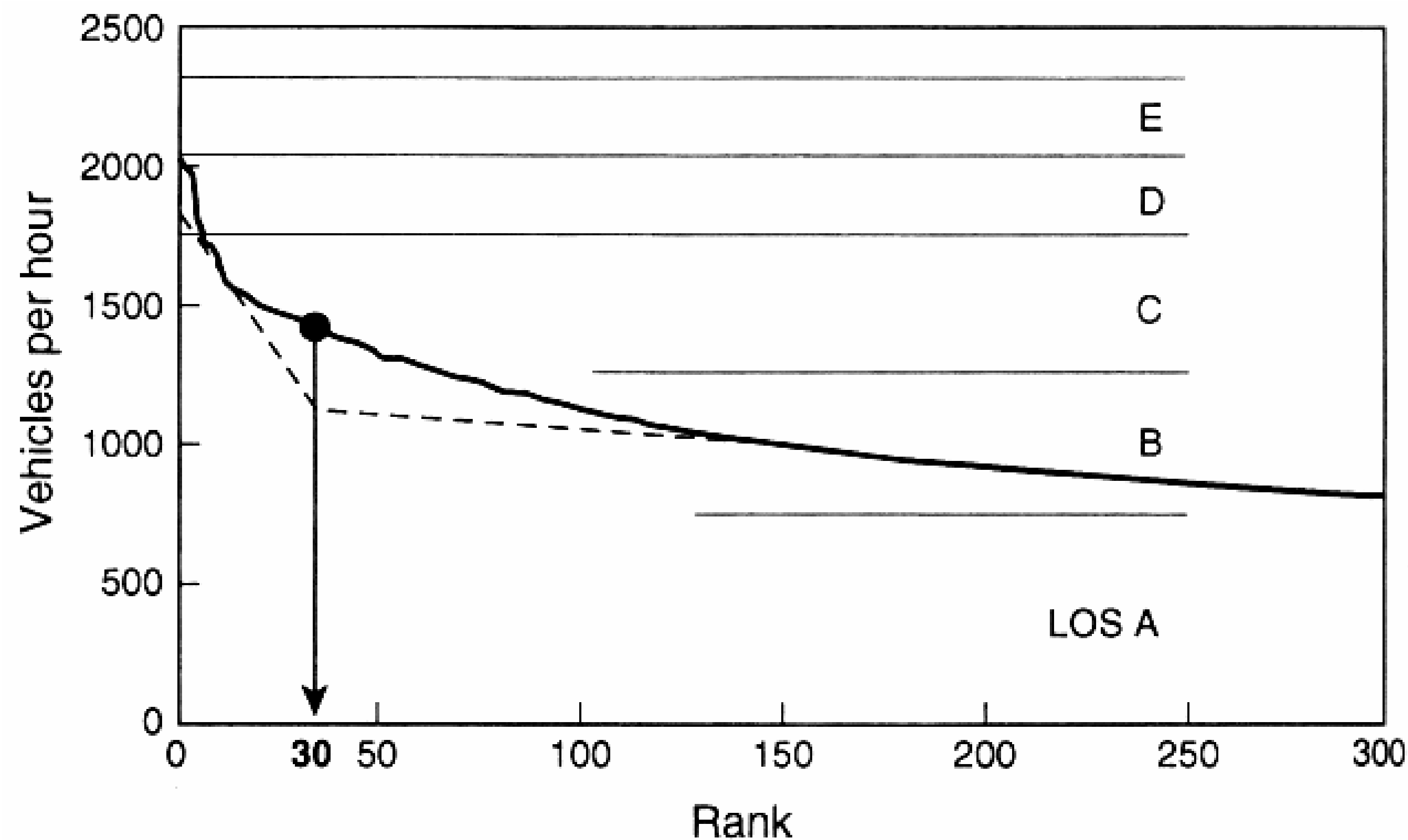
Link (Levels of service):

- n^{th} hour
- AADT (symmetric matrix)
- Average peak hour (asymmetric matrix)

Intersections (waiting time):

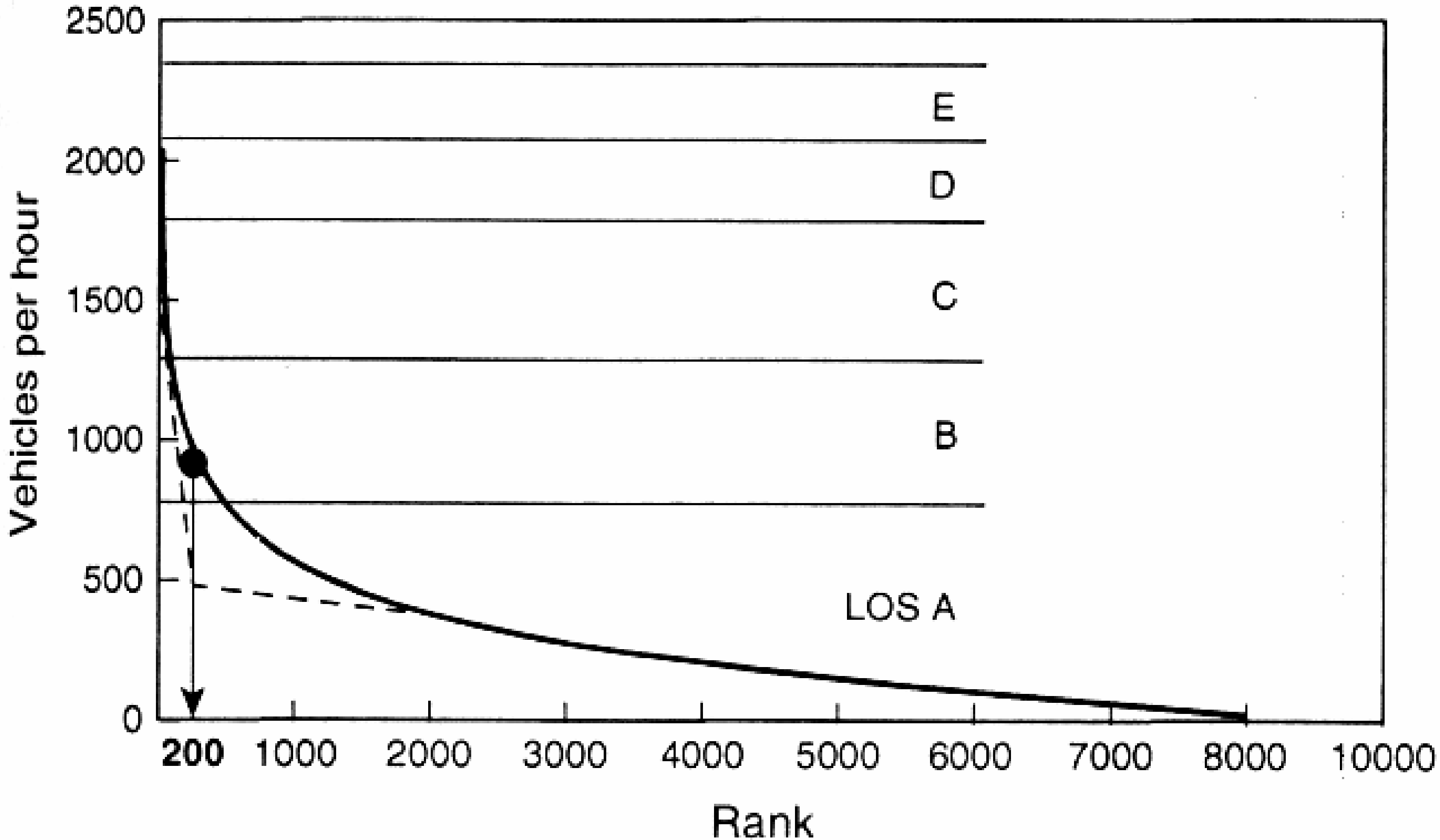
- 4 * peak quarter hour
- 1.2 * peak hour

30th Hour: the original measurements



Hempsey and Teply (1999)

Why not the 200th hour ? (Canadian measurements)



Hempsey and Teply (1999)

Ideal approach

Covers:

- Complete demand profile especially peak loads (remember we are dealing with queues !)
- Consistent across all elements of the road system
- Consistent with cost-benefit analysis
- (Reasonably) simple in application

Candidate ?

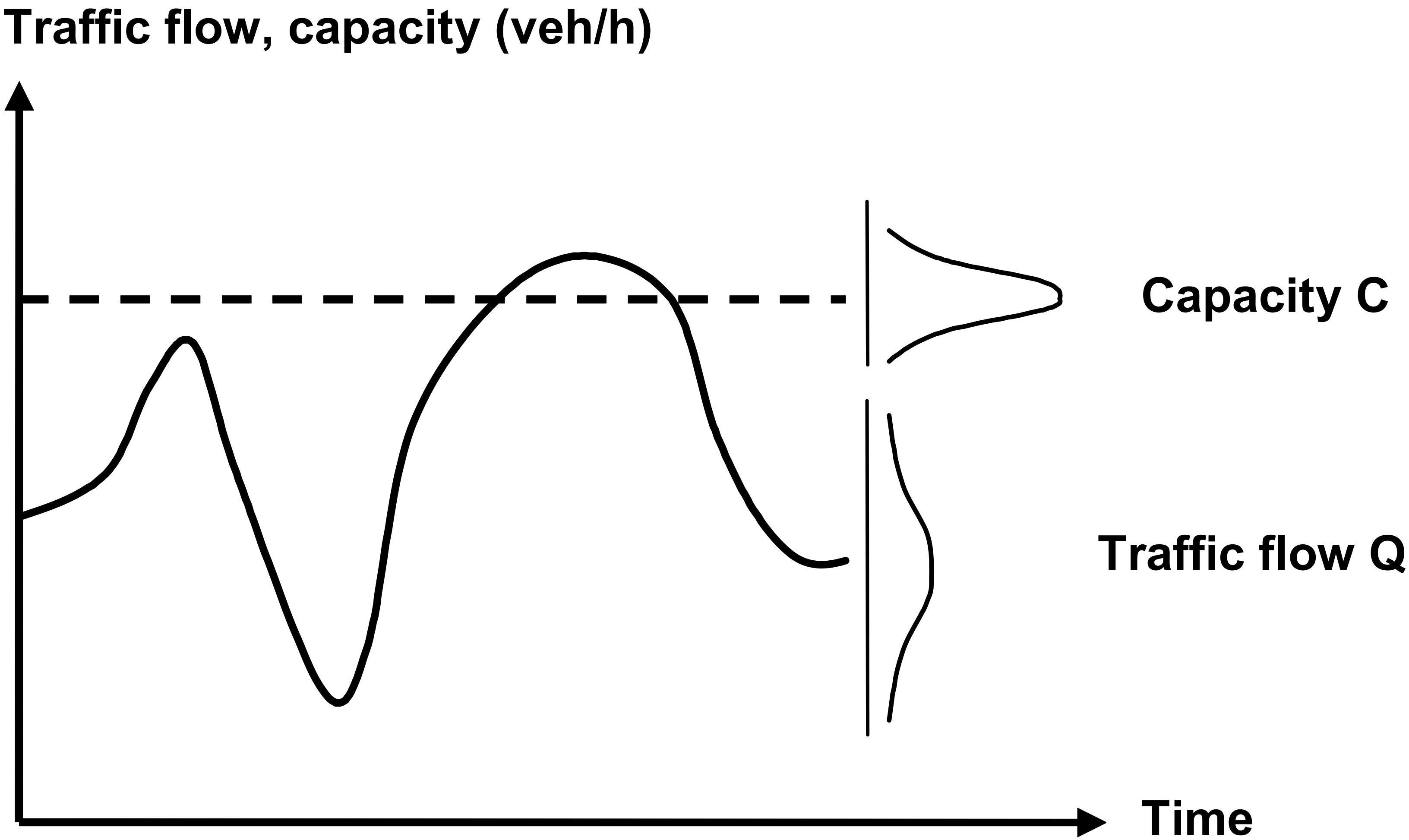
Concept of

distribution of the instantaneous reserve capacity R

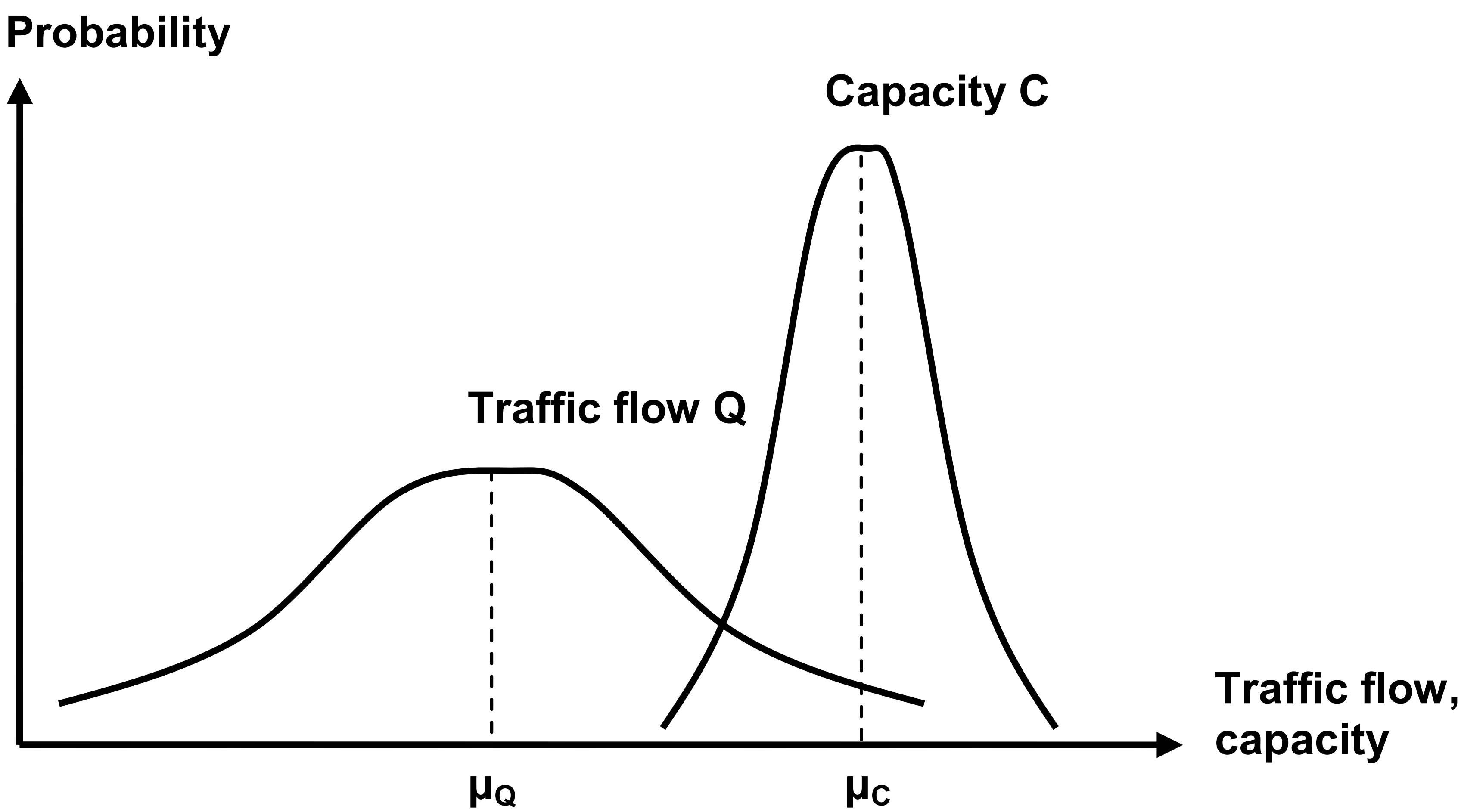
As difference between

momentarily available capacity C and
current demand Q

Why instantaneous C and Q ?



Why randomly distributed C and Q ?



Micro-variance of flow q

Question:

How large is the variance of the flow (5 min intervals) for the hourly values forecast ?

Measurement of the micro-variance

Data:

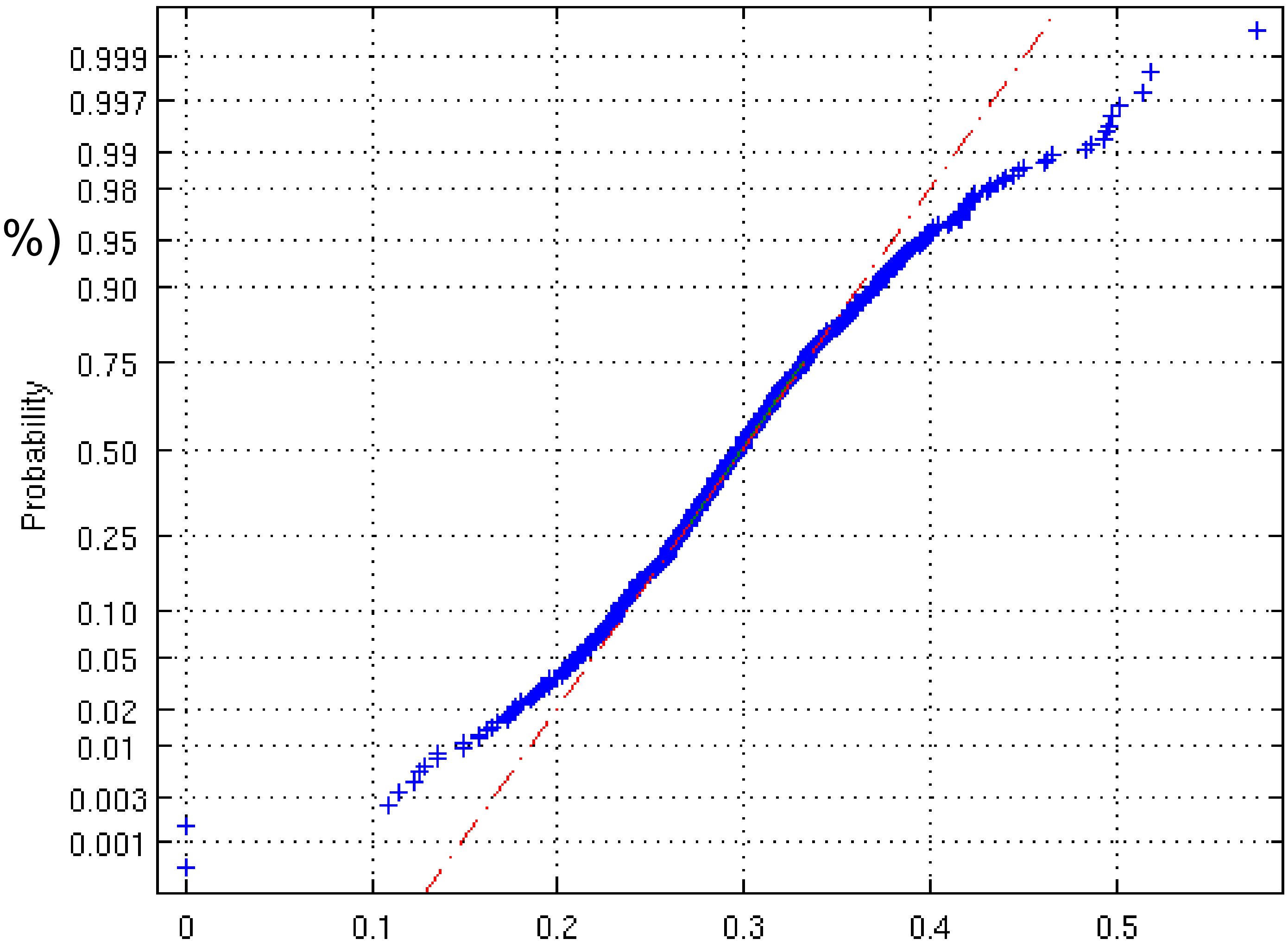
- 13 Swiss motorway cross-sections
- Between 180’000 and 330’000 5-min intervals

- Standardised relative with the current norm capacities (estimated for each cross-section)

Normal distributed flows given hourly q

r_{60} = 30%

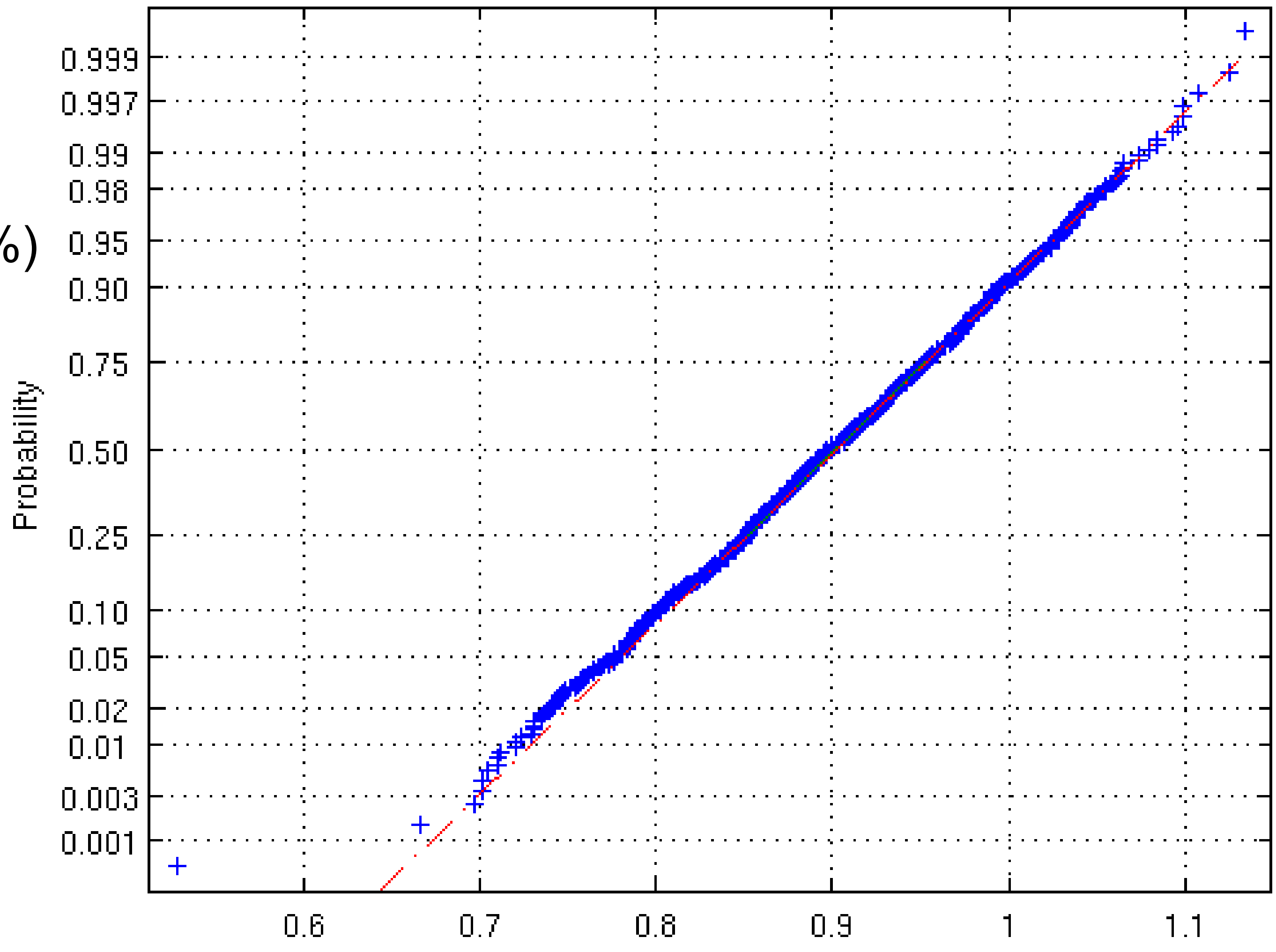
(Δr = 1.25%)



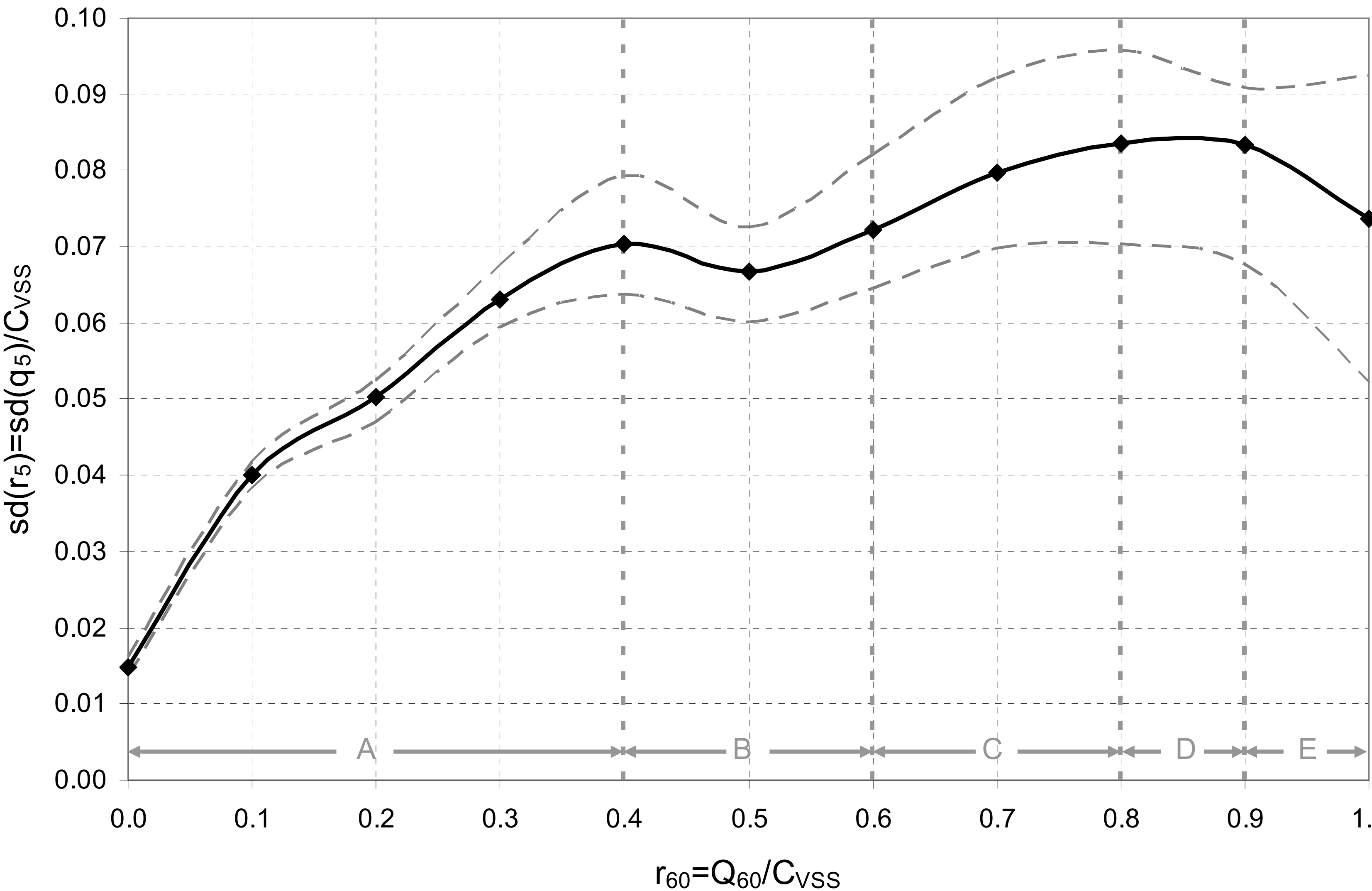
Normal distributed flows given hourly q

r_{60} = 90%

(Δr = 1.25%)

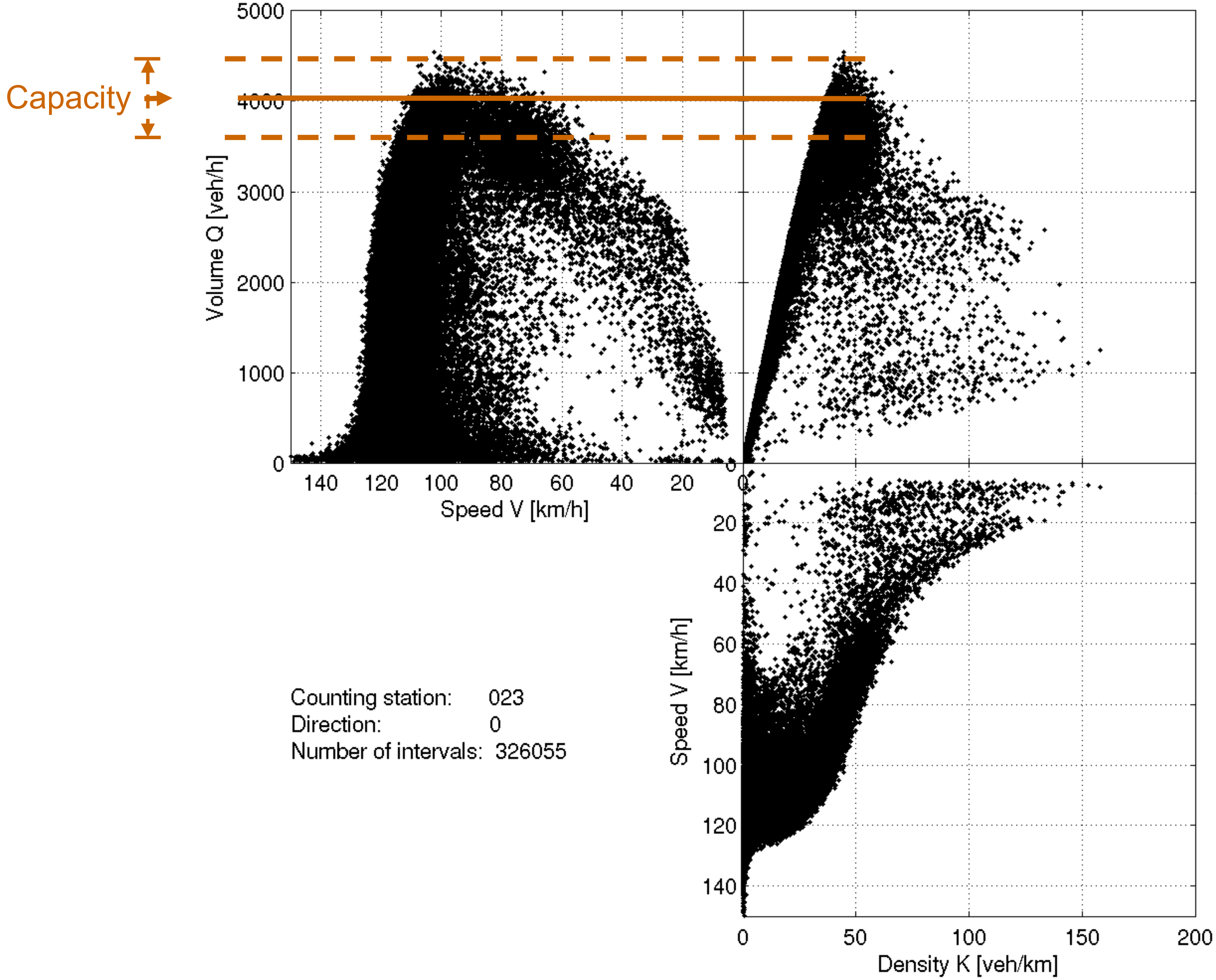


Micro-variance and hourly flows (Norm LOS)



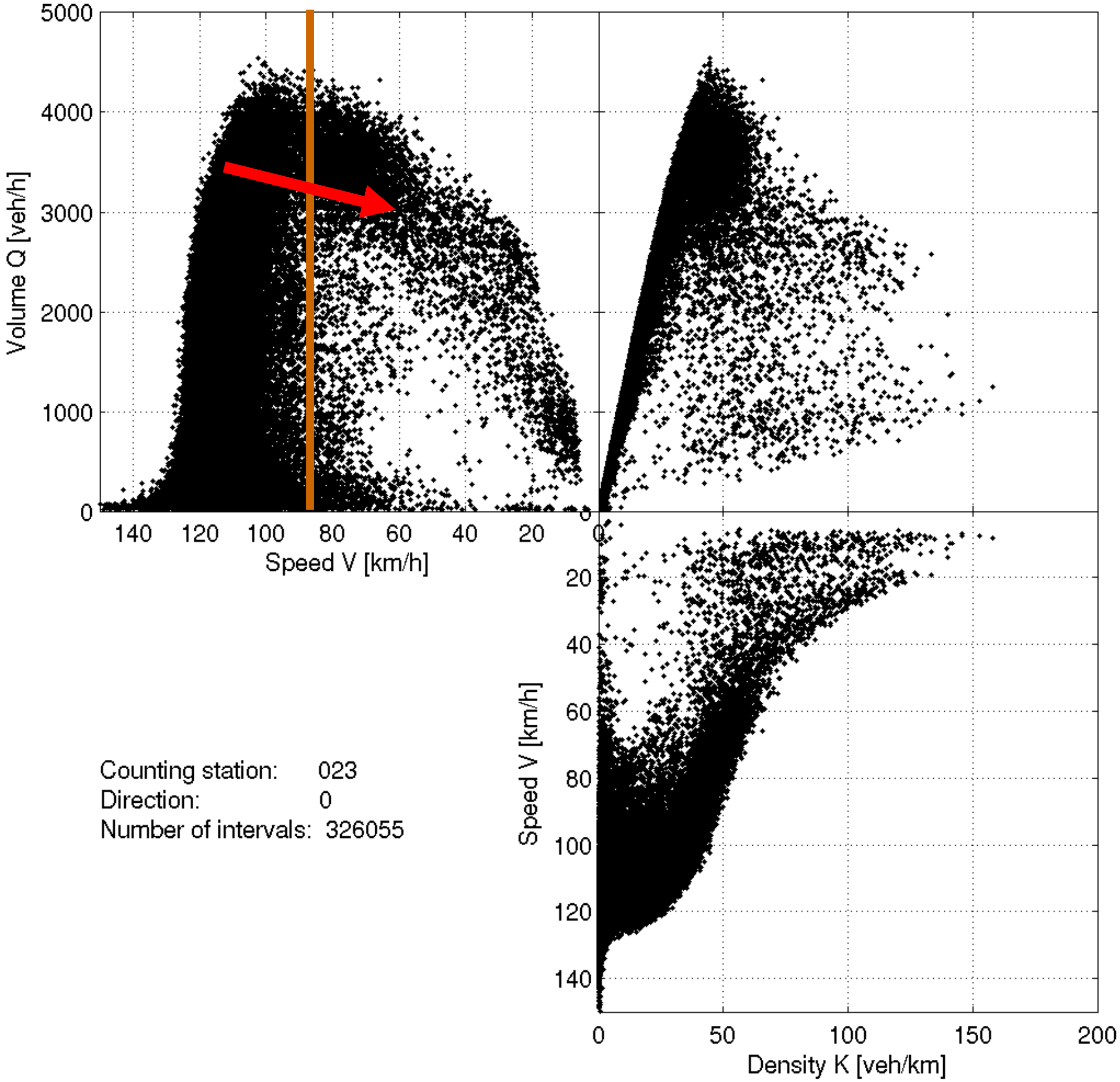
Capacity as a random variable

“HCM” - approach



Zählstelle Mattstetten, A1, Richtung Zürich

Breakdown as the indicator of capacity



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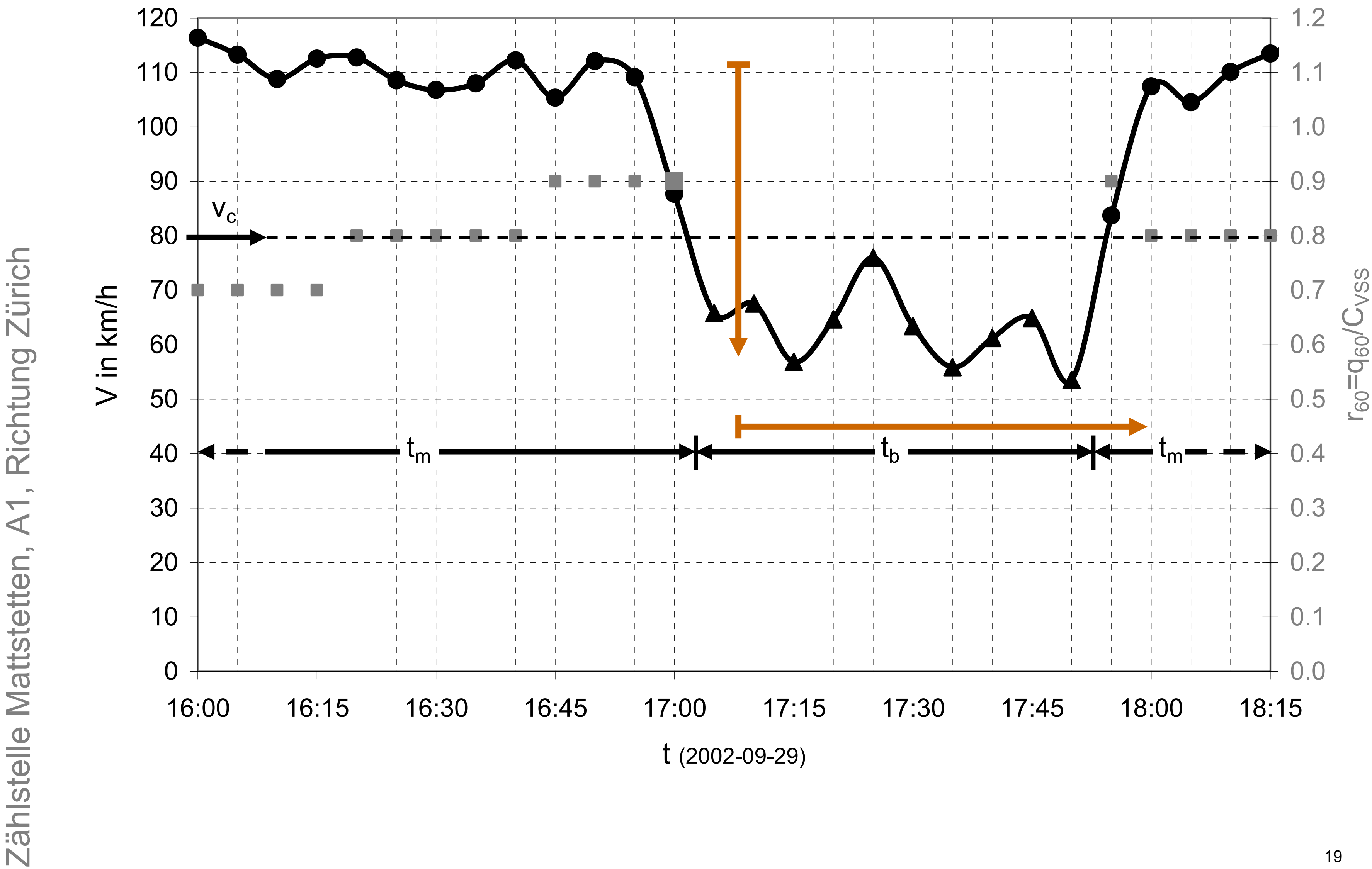
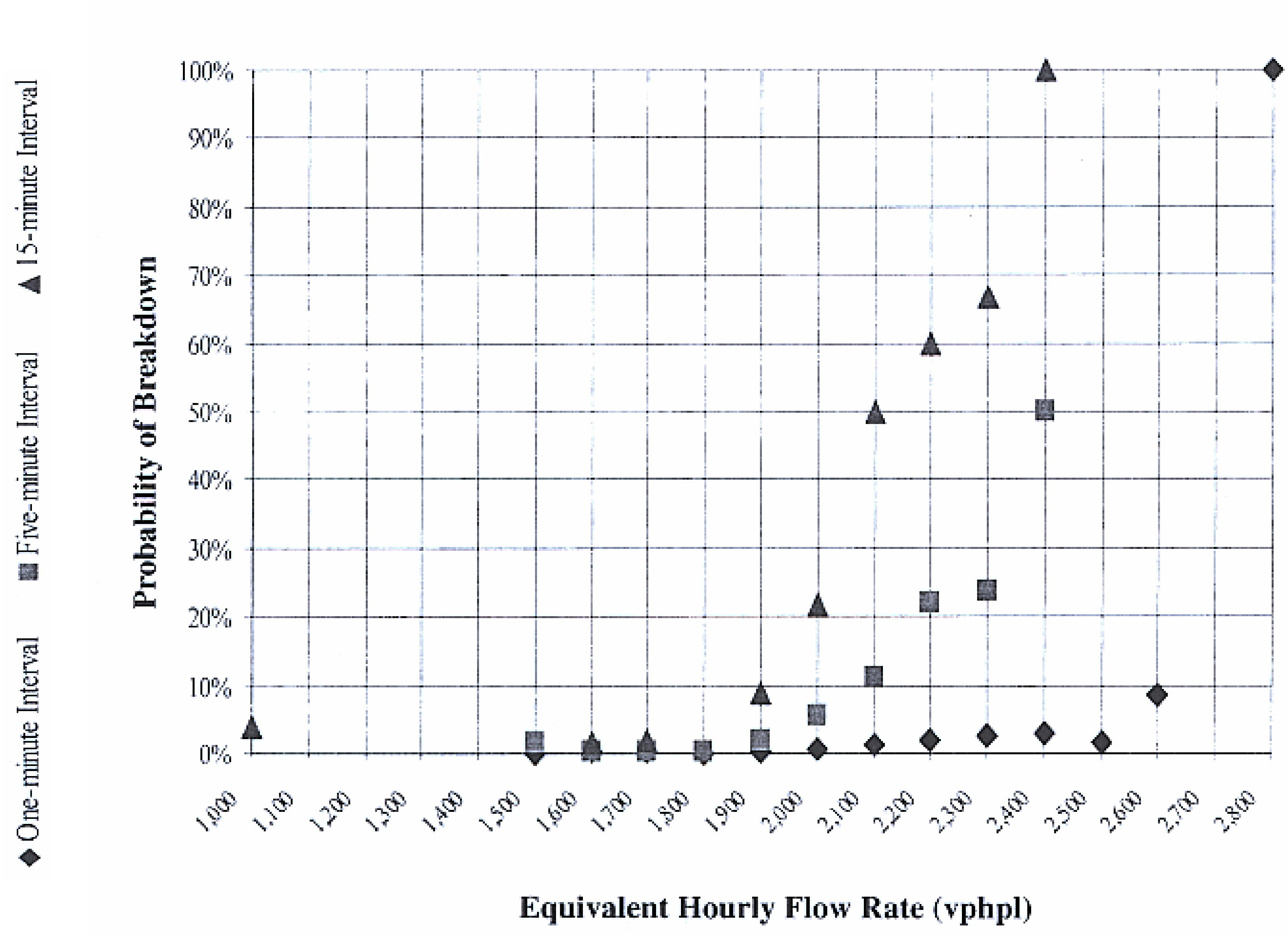
Definitions



Breakdown probabilities and aggregation intervals



Matt and Elefteriadou (2001)

Estimation via reserve capacity R

Assume $C \sim \mathbf{N}(\mu_C , \sigma_C)$ and $Q \sim \mathbf{N}(\mu_Q , \sigma_Q)$

Reserve capacity R is then:

$R := C - Q$

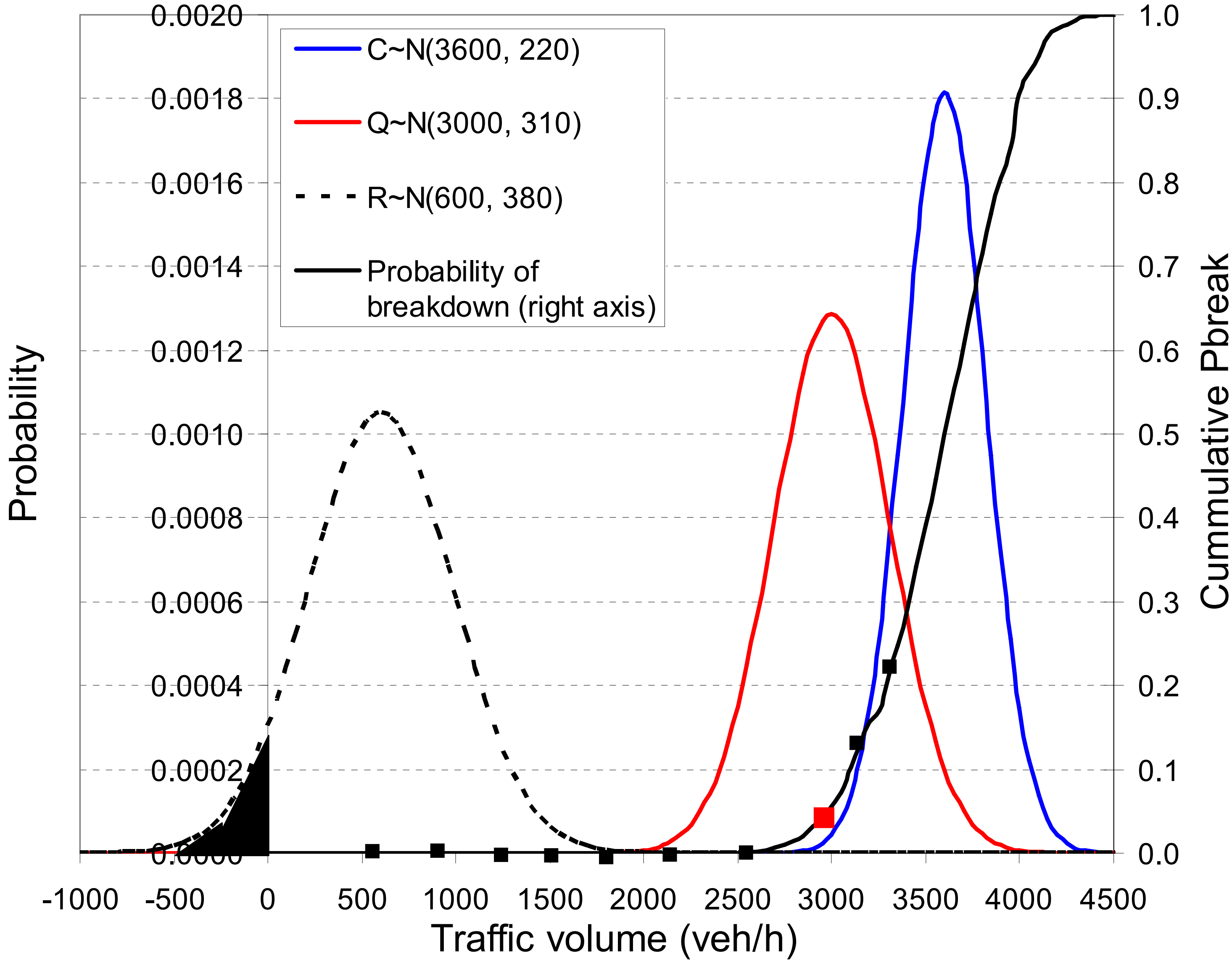
from which

$P_b = P(C \leq Q) = P(C - Q \leq 0)$
$P_b = P(R \leq 0)$

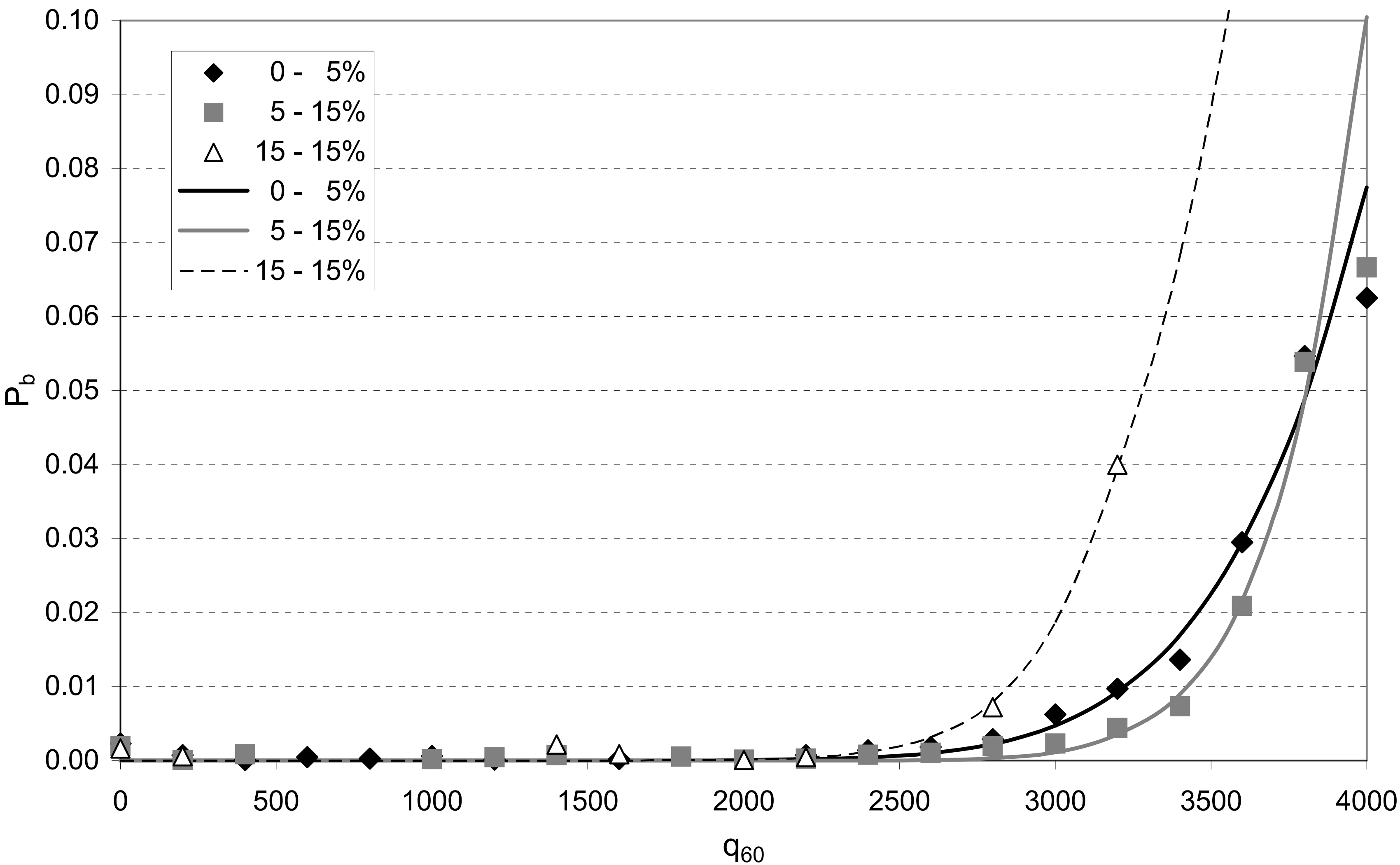
with $R \sim \mathbf{N}(\mu_R , \sigma_R)$

$\mu_R = \mu_C - \mu_Q$ and $\sigma_R = \sqrt{\sigma_C^2 + \sigma_Q^2}$

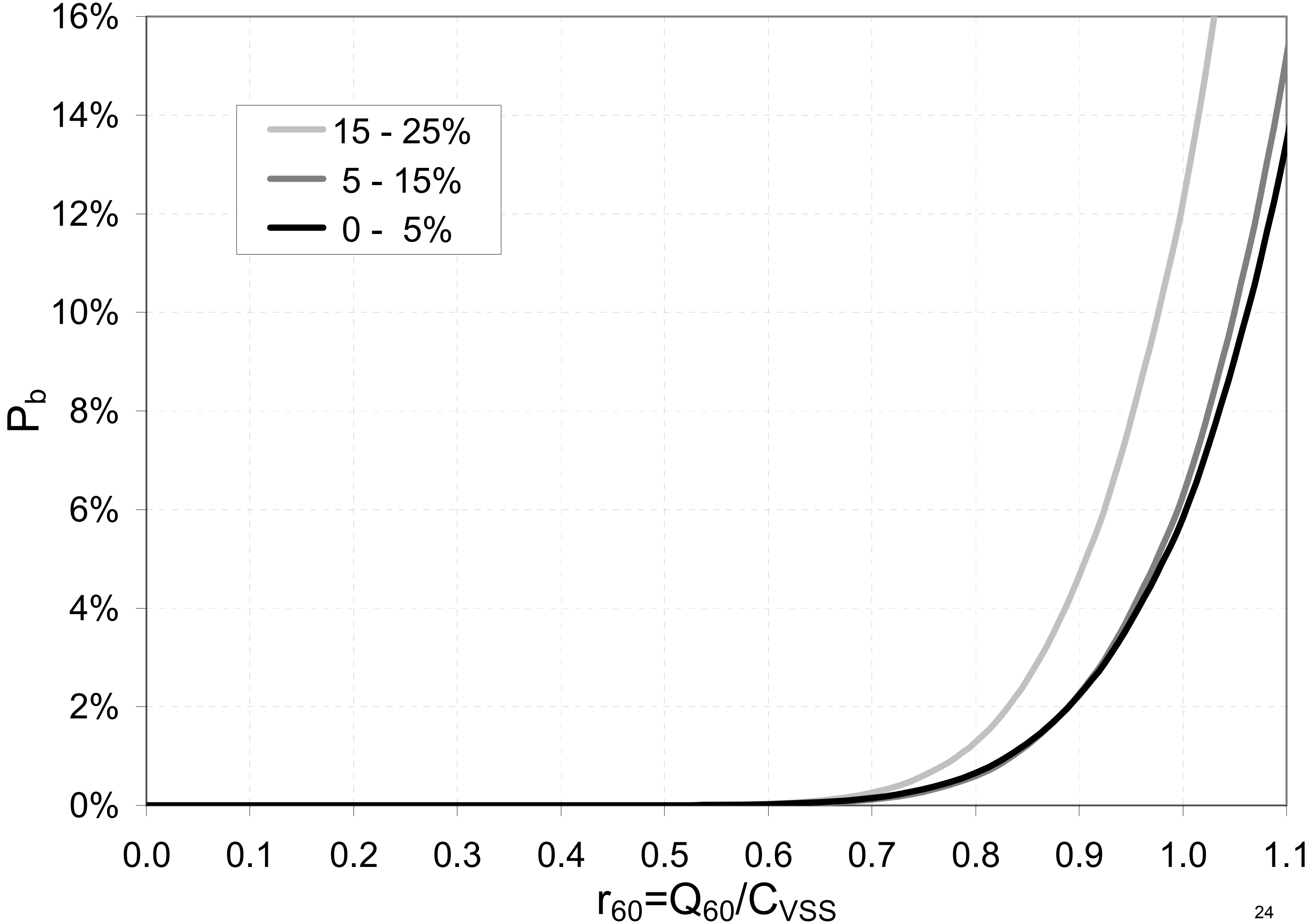
Breakdown probability



Breakdown probability Maatstetten



Breakdown probability as a function of flow Q

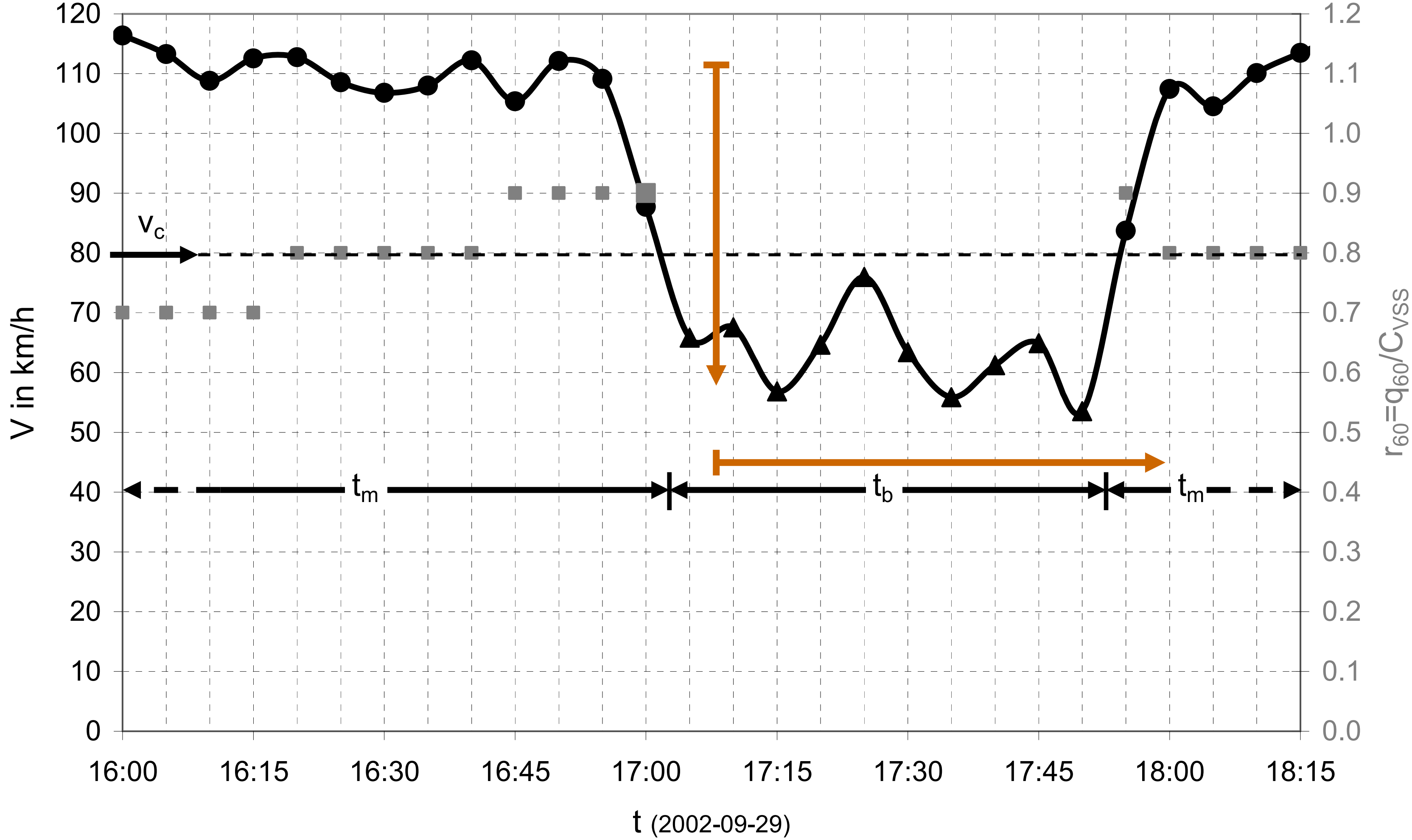


Random Capacity relative to C_{VSS}

Heavy Vehicle percentage	Median of mean capacities	Median of standard deviations
0 – 5%	1.327 $C_{VSS,0\text{-}5\%}$	0.197 $C_{VSS,0\text{-}5\%}$
5 – 15%	1.294 $C_{VSS,0\text{-}5\%}$	0.180 $C_{VSS,0\text{-}5\%}$
15 – 25%	1.206 $C_{VSS,0\text{-}5\%}$	0.164 $C_{VSS,0\text{-}5\%}$

Costs of a breakdown

Duration t_b of low speed



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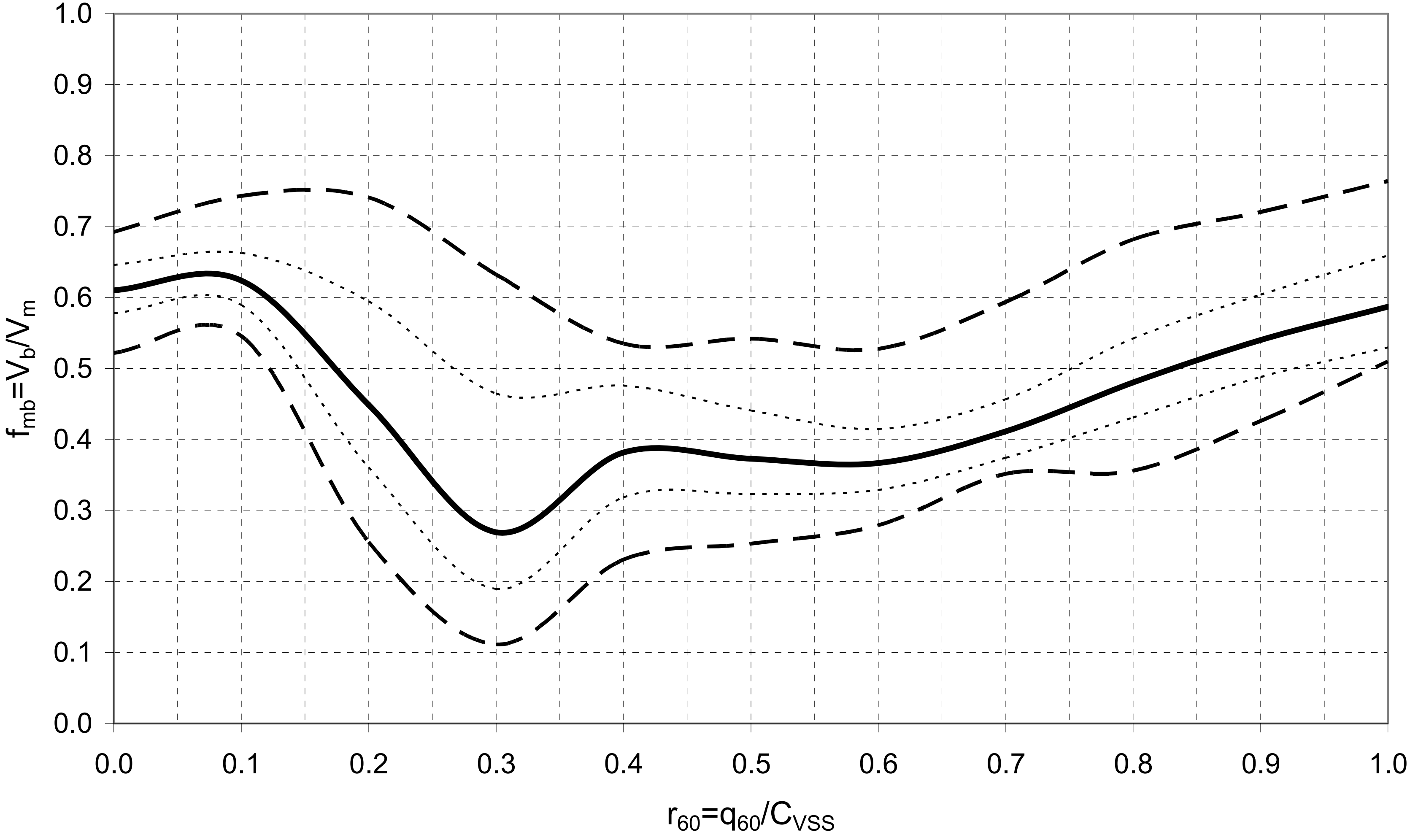
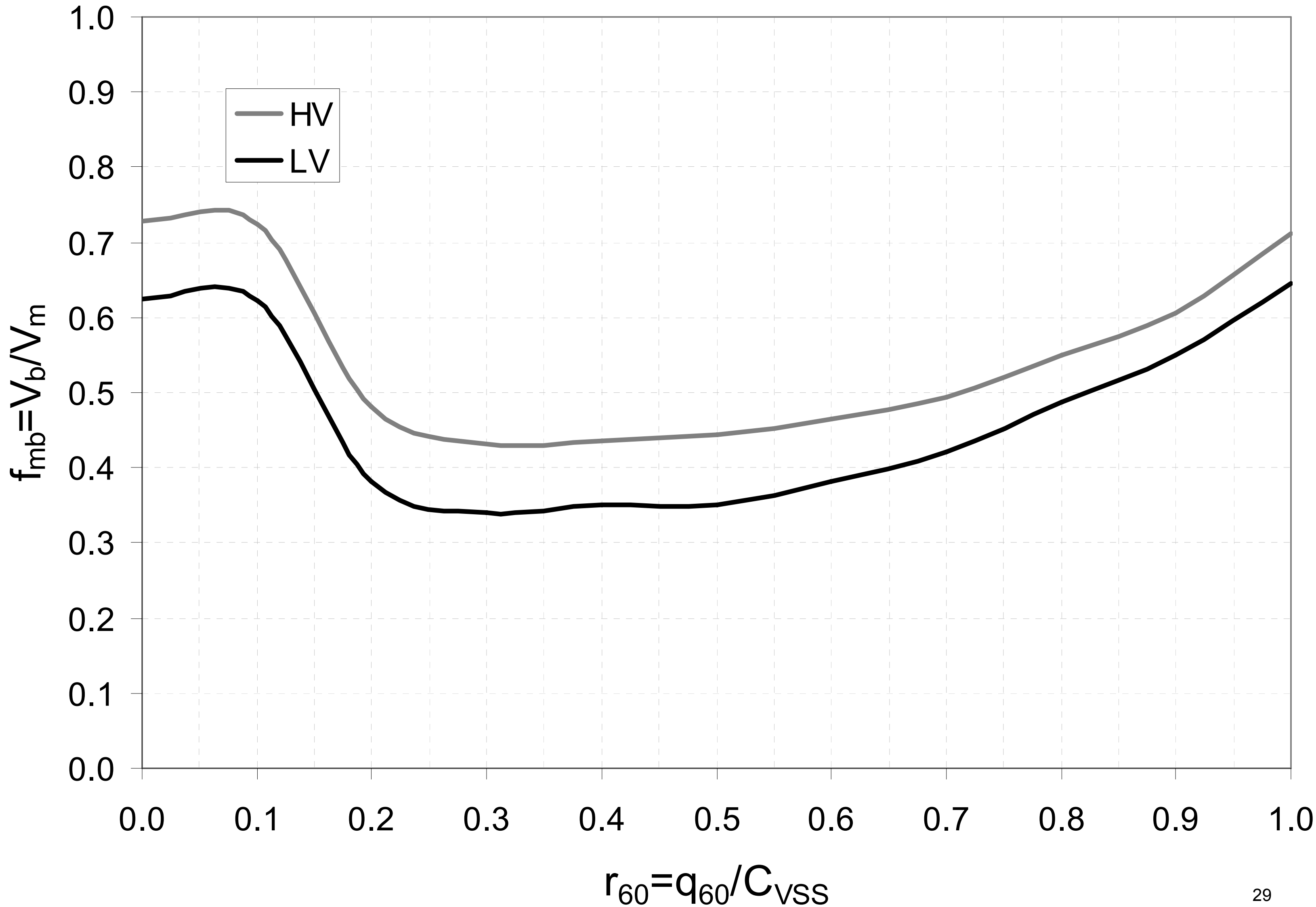
Speed reduction relative to free flow speed v_m

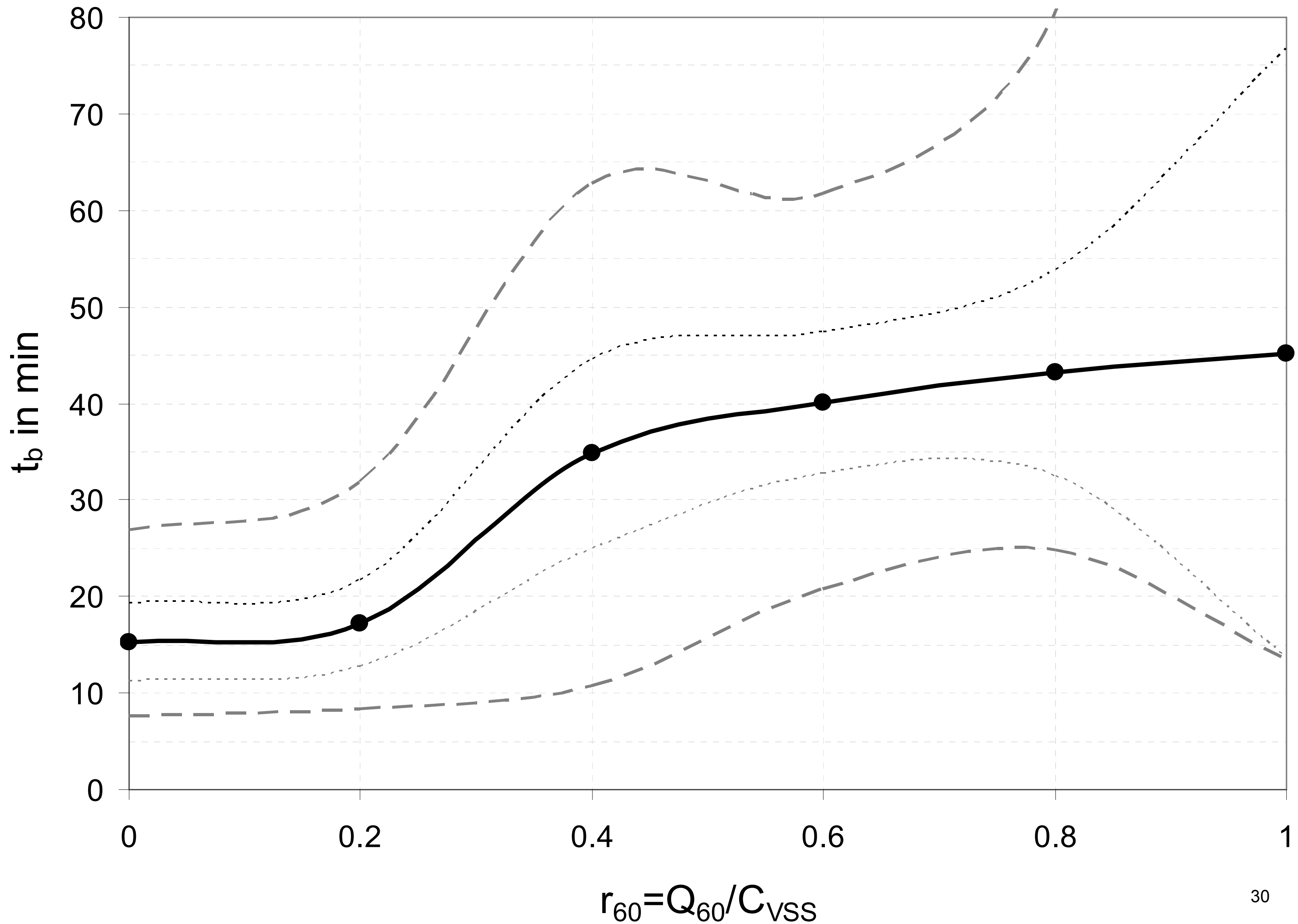


Heavy goods vehicles 0 – 5 %

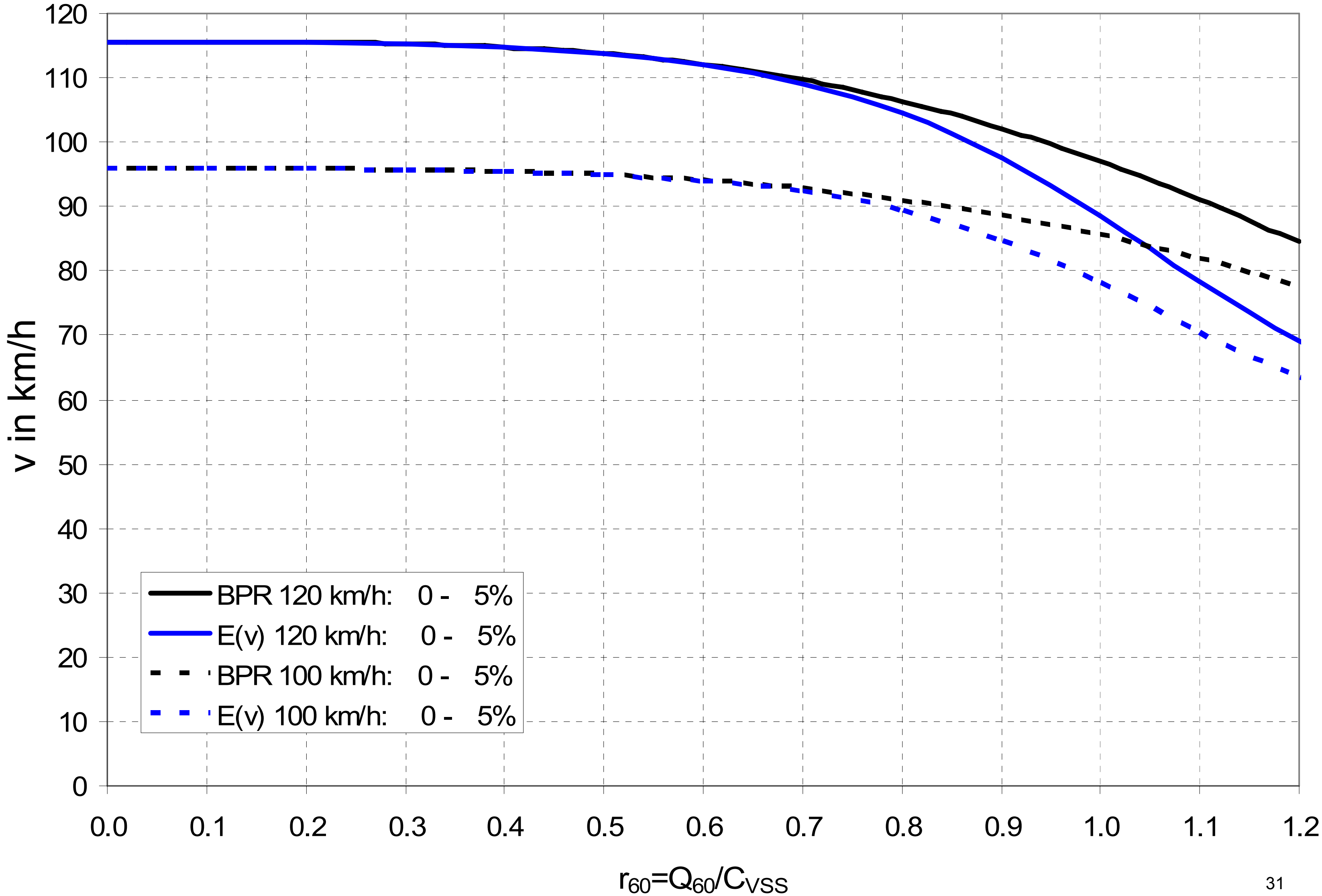
Speed reduction cars and heavy goods vehicles



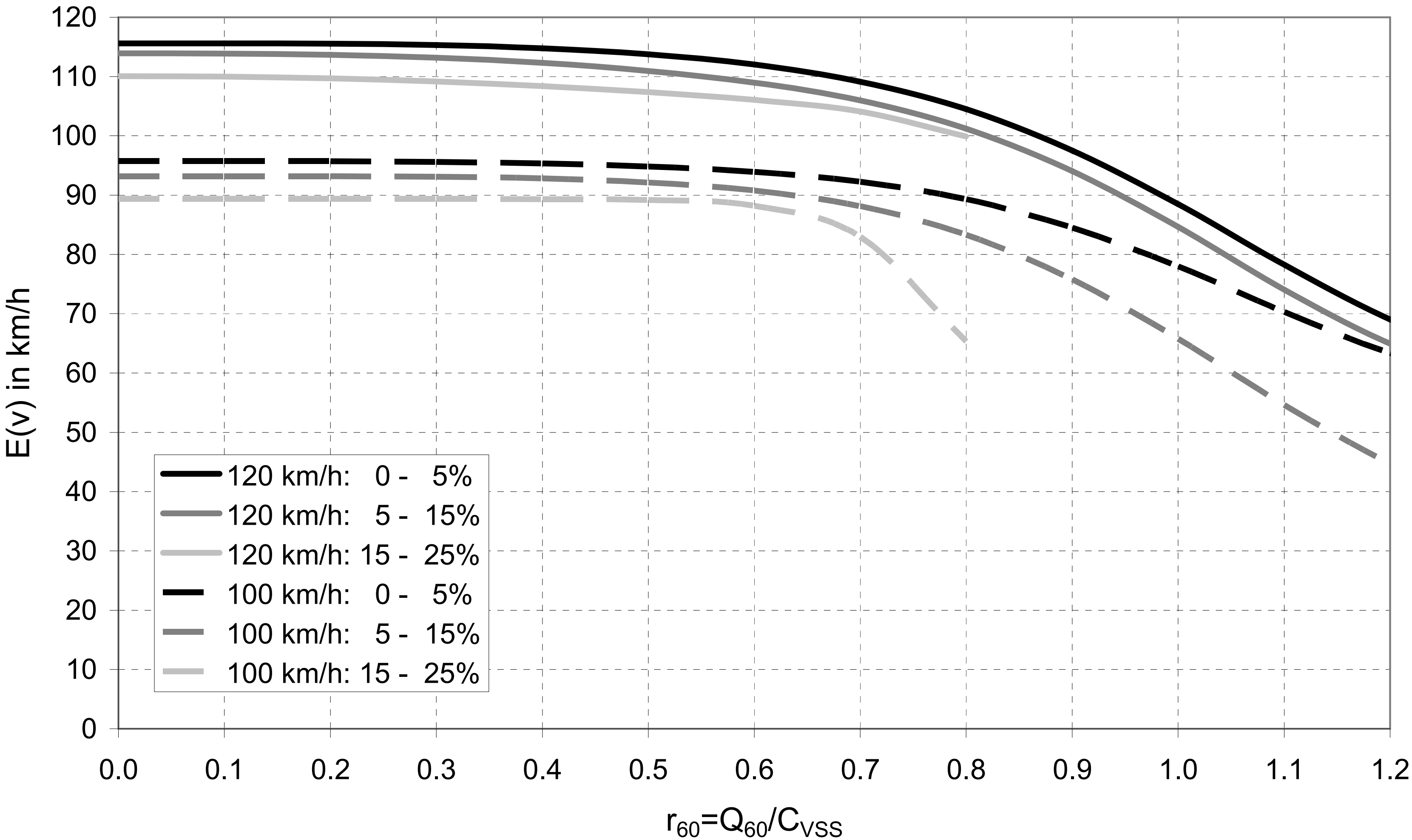
Breakdown duration



Speed with and without breakdowns



Speed (including breakdowns) by speed limit



Approximation of the user costs

Users N (with car occupancy $o_{\boldsymbol{o}}$):

$$N = o_{\boldsymbol{o}} \bullet Q_{60}$$

Value of travel time savings (VTTS):

$$COST_{\boldsymbol{tot}} = N \bullet (VTTS_{\boldsymbol{m}} \bullet t_{\boldsymbol{m}} + (VTTS_{\boldsymbol{m}} + VTTS_{\boldsymbol{b}}) \bullet \Delta t_{\boldsymbol{b}})$$

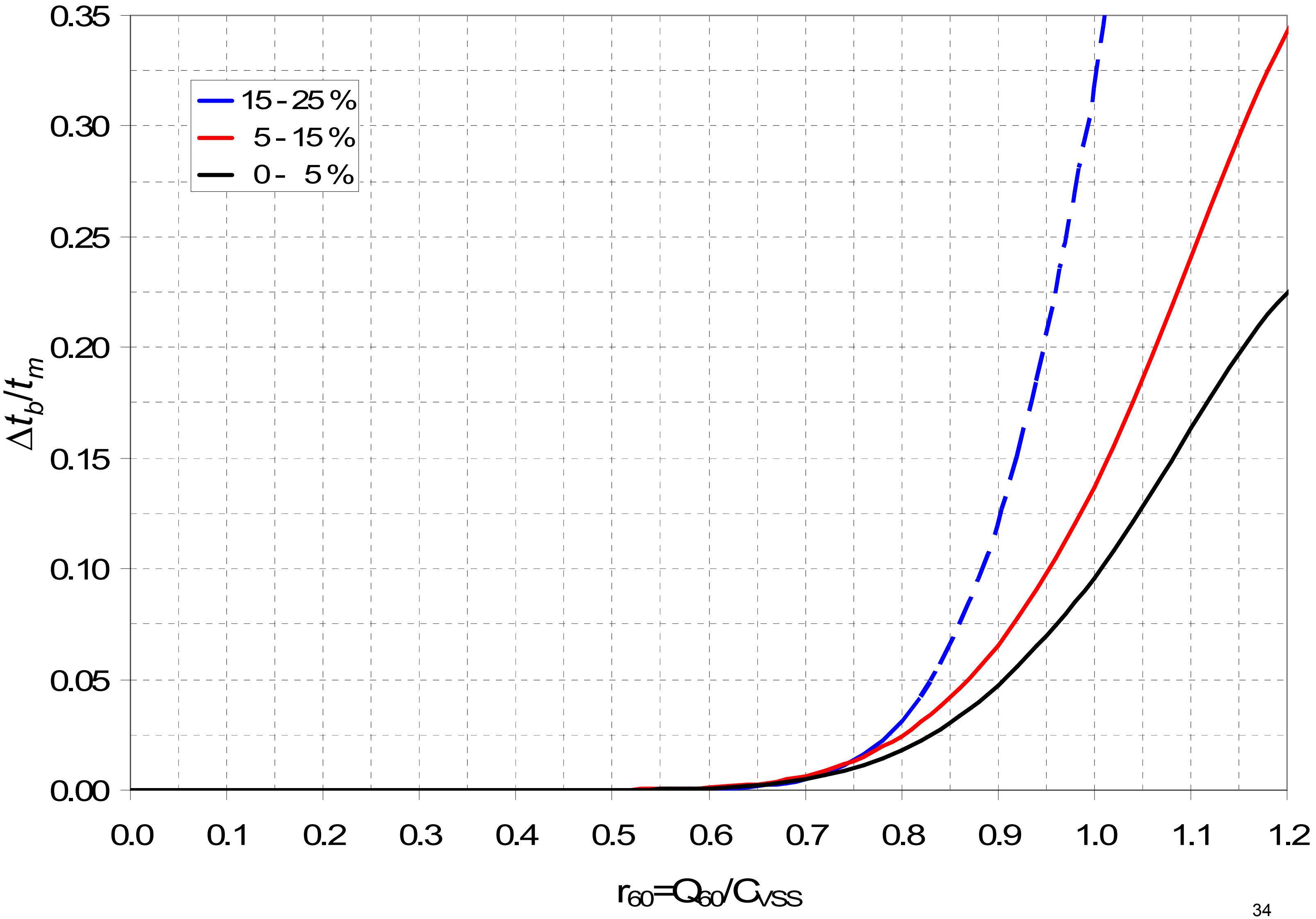
or for a km:

$$\frac{COST_{tot}}{s} = o_o \cdot Q_{60} \cdot \frac{1}{v_m}\left(VTTS_m + \left(VTTS_m + VTTS_b \right)\left(\frac{1 - f_{mb}}{\Delta t / P_b t_b + f_{mb}} \right)\right)$$

with function: $$v_m = \frac{v_0}{1 + \alpha\, r_{60}{}^{\beta}}$$

and $$\frac{\Delta t_b}{t_m} = \left(\frac{1 - f_{mb}}{\Delta t / P_b t_b + f_{mb}} \right)$$

Share of breakdown times (costs)



What has been achieved ?

- Detailed analysis of micro-variance
- Estimates of capacity as a random variable

- Reserve capacity as design tool for links

- Estimates of reserve capacities as random variables

- Cost estimates of breakdowns as a function of
  - Flow
  - Car occupancy
  - Breakdown probability
  - Breakdown duration
  - Share of heavy vehicles
  - Willingness to pay

What is missing ? - Outlook

- Standard demand profiles
- Link between peak hour and AADT
- Integration over the demand profile
- Non-linear penalty for lateness and unreliability